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AIR WAR COLLEGE

RESEARCH REPORT

ACQUISITION MANAGEMENT OF
ELECTRONIC WARFARE SYSTEMS

LT COL FREDERICK L. WESTOVER

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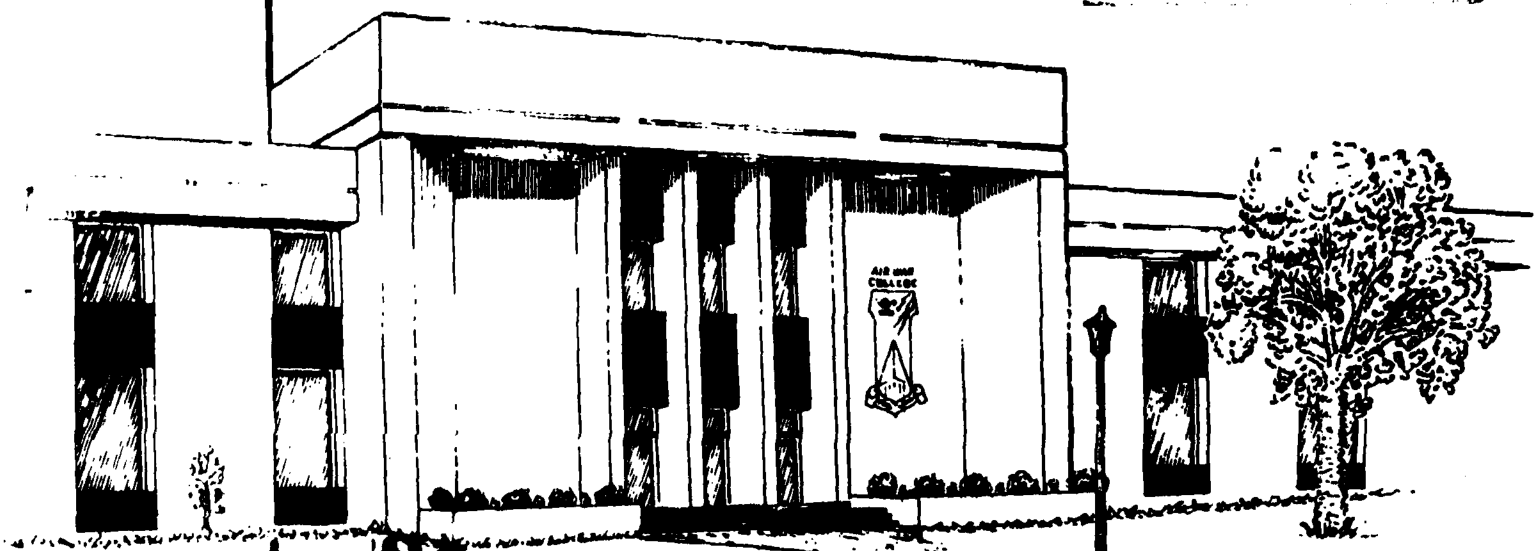

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UNITED STATES AIR FORCE
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AIR WAR COLLEGE
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ACQUISITION MANAGEMENT
OF
ELECTRONIC WARFARE SYSTEMS

by

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A THESIS SUBMITTED TO THE FACULTY

IN

FULFILLMENT OF THE RESEARCH

REQUIREMENT

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AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: Acquisition Management of Electronic Warfare Systems

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The Air Force continues to be challenged in acquiring the electronic warfare systems needed to counter the future threat. Fundamental to this challenge is the need to advance the state of the art in technology in order to beat the threat while controlling technical, schedule, and cost performance. To date, our track record is not impressive. Across the board, systems are being procured that fall short of user requirements, are years behind schedule, and are experiencing gross cost overruns. Can anything be done to improve the acquisition management of electronic warfare systems? The search for the answer has been difficult but provides some basic insights into the complexity of the acquisition process and identifies the essential elements needed to control program performance. The answer to successful acquisition management can be summarized as follows:

1. An experienced government/contractor team is required that has a strong management, systems integration, and technical background.

2. The team must make the necessary resource commitments to the program.

3. The team must have in-place an organizational infrastructure and the discipline to follow an orderly and controlled acquisition process.

4. Concurrency between development and production must be reduced, and a management plan implemented that ties key program decisions to the contractor meeting performance milestones.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Frederick L. Westover (M.S. in Systems Technology, Naval Post Graduate School and M.S. in Systems Management, University of S. California) has extensive acquisition management experience in a wide range of electronic warfare programs. In his previous assignment, he was responsible for the F-4G Wild Weasel Performance Update Program, Follow-on Wild Weasel system definition, the Tactical Electronic Reconnaissance program, and the EC-130H Compass Call development program. Before that he served as flight test director for the F4-G Wild Weasel development test and evaluation and as technical advisor for the F-16 penetration aids and B-1 defensive system flight test programs. He is a graduate of the Naval War College's Naval Command and Staff and a graduate of the Air War College, class of 1988.

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INTRODUCTION

Air Force Systems Command continues to be challenged in acquiring the electronic warfare (EW) systems needed to counter the future threat. Fundamental to this challenge is the need to advance the state of the art in technology in order to beat the threat while controlling technical, schedule and cost performance. To date, our track record is not impressive. Across the board, systems are being procured that fall short of user requirements, are years behind schedule, and are experiencing gross cost overruns. Over the last few years much has been written about the systems acquisition process, and a host of new policies and regulations to control the process have been implemented. In this paper I address the question "Can anymore be done to improve the acquisition management of electronic warfare systems?" Based on my research, successful acquisition management can be summarized as follows:

1. An experienced government/contractor team is required that has a strong management, systems integration, and technical background.

2. The team must make the necessary resource commitments to the program.

3. The team must have in-place an organizational infrastructure and the discipline to follow an orderly and controlled acquisition process.

4. Concurrency between development and production must be reduced, and a management plan implemented that ties key program decisions to the contractor meeting performance milestones.

After setting the stage in terms of the EW challenge, the following fundamental areas of the acquisition process will be examined in terms of problems and steps needed for successful program management:

1. Development of program requirements.
2. Source selection.
3. Government/contractor team.
4. Program control.
5. Full scale engineering development (FSED).
6. Transition into production.

In this paper the observations and research are based on the author's experience on the F-4G Wild Weasel Performance Update Program (PUP), the EW Area Reprogramming Capability (ARC), the B-1 defensive avionics program, and the EF-111 upgrade program. While EW is specifically addressed, the problems as well as the conclusions and recommendations apply to other system acquisition programs as well.

For the purpose of this paper, the following assumptions have been made:

1. The acquisition manager's job will not become easier in the future.
2. The EW threat will be difficult to quantify.
3. Emphasis will be placed on high technology to offset Soviet numerical advantages.
4. Pressures will exist to shorten the acquisition cycle.
5. Congressional oversight will continue.
6. Defense budgets will continue to decrease.

THE ELECTRONIC WARFARE CHALLENGE

The Threat

The Soviet Union remains the number one threat to U.S. security and national interests.(13:6) Over the last two decades, the Soviet EW threat has significantly increased in terms of threat types and signal densities. As compared to the threat of the late 60's, the number of different types of threats (i.e. early warning, target acquisition, target tracking, and missile guidance systems) has increased three fold, and the signal density has increased thirty fold.(2) Also, the threat has advanced to include emitters that have incorporated low probable intercept (LPI) emission techniques which make detection by our current EW systems extremely difficult. LPI emitters operate with narrow beam widths, short transmission times, and sophisticated waveforms.

The advanced Soviet threat in terms of threat types, signal densities, and LPI techniques requires our future EW systems to respond much faster than current systems by incorporating highly complex receiver, processor, and jamming capabilities. In other words, we must push technology to beat the threat.

Some critics of the EW acquisition process believe the Air Force overstates the threat which results in high risk system designs that cannot be implemented within program cost and schedule constraints. They argue that direct conflict with the Soviet Union is extremely unlikely and our focus should be towards low intensity conflicts in the Third World against "less sophisticated threats". Future conflicts would be similar to what the

Israelis encountered against Syrian air defense systems in 1982 or what the U.S. experienced against Libya in 1986. In both cases, EW systems developed in the late 60's and early 70's were used to counter a somewhat dense but unsophisticated Syrian and Libyan threat environment.

The outcome of both conflicts were embarrassments to the Soviets, who have since rearmed Syria and Libya with more and improved air defense systems. In the future, we cannot assume that the Soviets will only export older, less sophisticated systems to their client States. Also, both conflicts occurred over a short duration where the elements of surprise and tactics played an important role. Today the enemy is better prepared, and our success rate would decrease, particularly when faced with the increased signal densities. Finally, the EW acquisition process requires 10 to 12 years to field a new or improved system. The SA-5 and SA-6 that were used by Syria and Libya required the U.S. to advance EW technology in the late 60's and early 70's. For the future, the SA-10, SA-11 and SA-12 require the U.S. to advance technology today. Given the time it takes to field a system, we must push technology now in order to defeat the threat of the future.

While it is unlikely that the U.S. will fight the Soviet Union, it is possible that we will encounter a future Soviet threat (i.e. SA-10) in a third world country that our current EW systems cannot defeat. We have not overstated the threat, and a reality of EW is high technology. The problem we face in acquisition is managing the risks associated with implementing high technology.

The Technical Challenge

The EW technical challenge can be translated into some basic system capabilities that drive hardware and software requirements. Typically, new technology is needed to meet these requirements in terms of speed, packaging, weight, and power consumption. Examples of new technology include the development of microwave integrated RF circuitry to obtain miniaturization, gate arrays to reduce size and increase speed, low power RF mixer amplifiers, and components that perform over broad RF bandwidths. Also, EW systems are integrated into high performance aircraft which place severe environmental constraints on system operation. System integration probably presents the greatest technical challenge. EW systems consist of numerous line replaceable units (LRUs) that include antenna arrays, receivers, transmitters, signal processors, displays and power sources. For example, the B-1 defensive system has over 100 LRUs. It is extremely difficult to successfully integrate these LRUs within system performance requirements and without causing electromagnetic interference among the various units. Finally, the EW system must have high reliability, and if failures do occur, they must be readily identified, isolated, and corrected.

Taken together, these technical challenges translate into moderate to high risk EW programs. Steps must be taken throughout the acquisition cycle to reduce and control these risks.

THE ACQUISITION MANAGEMENT PROBLEM

Acquisition managers need to control program uncertainties in terms of technical, cost, and schedule performance. This becomes extremely challenging given the high technology associated with EW systems.

Defining Performance Requirements

At the center of the EW acquisition management problem is the need to advance the state-of-the art in order to counter the future threat. Off-the-shelf hardware often does not meet performance requirements. To counter the threat requires tight performance specifications at the system level and even tighter specifications at the subsystem level. It is difficult to successfully translate system requirements into subsystem, LRU, and board or module requirements. For example, how does a design engineer translate system performance requirements of reaction time and location accuracy into designs for specific RF and processing circuits? This is not easily done without extensive modeling and breadboarding. Even then, the performance is uncertain until actual hardware is developed, integrated and tested.

Forecasting Cost and Schedules

Due to the design uncertainties, acquisition managers have been unable to accurately forecast program cost and schedules. Past track records for EW systems show that they experience significant cost overruns and are years behind schedule. For example, in 1987 the receiver being developed under the F-4G Wild Weasel PUP was projected to incur a 77% cost growth and a four year slip in production deliveries.(14) Some may argue that managers

deliberately underestimate cost and schedules in order to sell their programs. As the argument goes, if the truth was known, no program would ever receive support from Congress. While acquisition managers are not dishonest, they tend to be overly optimistic in estimating cost and schedules and tend to underestimate the risks associated with developing new technology. For example, they may assess the technical risks as low to medium when in fact the risks are medium to high and estimate their cost and schedules on the former assessment.

Assessing Program Risks

Over the last several years, much has been written about the systems acquisition process, and a host of new policies and regulations to control that process have been implemented. While the jury is still out on how well these reforms are working, preliminary indications are that not much has changed in our ability to control the acquisition process.

Even though managers try to do everything possible to shorten the acquisition cycle, experience shows that it still takes 10 to 12 years to field a new or improved EW system. It can take even longer if attempts are made to unrealistically compress schedules, understate technical risks, or take shortcuts regarding system development, integration and test. Under these circumstances, a system may meet delivery schedules but not meet performance requirements. To correct these performance deficiencies requires extensive modifications at significant additional cost. Steps can be taken to keep risks at a medium level, but schedule compression and short cuts regarding system development, integration and test only increase risks and have little chance of success.

Assessing a program realistically in terms of technical risks and estimating cost and schedules accordingly would be an important step in controlling the EW acquisition process. For planning purposes, technical risks should be assessed as medium to high, schedules should be based on a 10 to 12 year acquisition cycle, and budgets should be in line with technical risks/ schedules. (Recommendation R1)

DEVELOPMENT OF PROGRAM REQUIREMENTS

Development of Technical Performance Requirements

In order to develop system performance requirements, the threat must be defined. This definition is largely based on assumptions and projections from the intelligence community. In some cases, the job is made easier through exploitation of actual Soviet equipment or collection of electronic intelligence. Unfortunately, little quantitative data exists that accurately describes the future threat. Consequently, performance requirements are often defined in terms of worst case scenarios. Various threat scenarios can be modeled, and performance requirements can be derived from the results. Often the technology does not exist to support the performance requirements, and the state-of-the art must be advanced. System design becomes a revolutionary versus an evolutionary process even though many EW programs are advertised as performance "updates" to existing systems.

From the start, EW programs can get into trouble by not recognizing that significant design improvements are needed to counter the threat. Given the threat, EW systems are being designed to include expanded frequency coverage, monopulse processing capabilities, complex waveform demodulation/modulation techniques, and accurate location measurement capabilities; all of which drive the state-of-the art in terms of system timing, packaging, and power consumption. Is all this necessary? Since employment of our EW systems usually lags the threat, the answer is probably yes. However, obtaining the required EW capability will be expensive.

As a part of the requirement definition process, definition studies and industry surveys may have to be conducted to identify the technical risk areas. If the technology is not in hand, is not being developed in a government avionics laboratory, or is not being developed by industry, then serious consideration should be given to making trade-offs between technical risk, cost, and system performance. If it is critical that the EW system be fielded early, then system requirements must be relaxed and performance shortfalls accepted until the technology becomes available. On the other hand, it may be more critical to develop the technology and accept the schedule delays. If this approach is followed, it must be done in an orderly manner in which definition studies, risk reduction efforts, and the development of engineering models precede the development of qualified (preproduction) systems. (R2)

Development of Cost and Schedule Estimates

Once the system performance requirements are defined, then cost and schedule estimates for the entire acquisition process need to be developed. In the beginning of a program, this is extremely difficult since the technical risks are medium to high. In some cases the technology is not in hand. A program manager knows that he will experience problems; the magnitude and impact of those problems are unknown. Nevertheless, cost and schedules are estimated based on modeling, past experience and industry inputs. Program managers tend to be too optimistic in developing these estimates even when faced with significant technical challenges. They may believe that an overly optimistic approach will help sell their program, and

once started, the past trend has been to keep funding programs. In other words, once a program starts, the risks of cancellation are small.

If during the development of cost estimates the required funds don't match the approved funds, restructuring should occur, and funding shortfalls should be worked in the out years through the POM process. Under these circumstances, a slower (lower risk) start up occurs which is more in line with the costs for definition studies, risk reduction efforts, and development of engineering models mentioned previously. A particular phase of a program should not start unless the required and approved funds match in the current and upcoming budget years.

In today's environment of cuts in defense spending, programs that cannot stay within their budget are being cancelled. The Precision Locating Strike System, the EW Area Reprogramming Capability, the self protection system for the F-111 aircraft, and the F-4G Wild Weasel Performance Update Program represent examples of programs that have been recently cancelled due to cost problems. In order to assure the viability and executability of EW programs, program managers must base their cost and schedule estimates on a realistic assessment of technical risks. This must be addressed up front before the acquisition cycle begins. (R3)

Development of an Acquisition Strategy

The outcome of the developing program requirements should be a system level development specification and "model" contract. Both will serve as the basis for executing the acquisition program and should be closely reviewed by both government and potential contractors to assure reasonableness. We do not want a contractor to sign up to a program that re

can't execute or for the government to include requirements that add little or no value to the end item. The contracting strategy for the entire acquisition cycle from definition studies through FSED and production must be thoroughly planned and well thought out to avoid serious contractual problems.

Recent government contractual policies designed to prevent contractor overpricing and fraud have created an adversarial relationship between government and the defense industry.(12:80) These policies have reduced industry's profit margin and have required companies to share more of the development cost and investment requirements which have created an adverse shift in the contractor risk-return balance. General Bernard Randolph, Commander of Air Force Systems Command, acknowledged that "industry right now is really being stressed, in my view, considerably".(10:36) For example, a design competition formerly required about one dollar of contractor investment for each dollar of government funding. The Advanced Tactical Fighter competition, according to Aviation Week and Space Technology, would use "four to five dollars for each government dollar, a poor payback".(12:80) Congress and the Defense Department have overreacted to allegations of overpricing and fraud of the early 1980's. Many corrective measures are being imposed that are viewed by industry as unprofitable contract terms. Consequently, companies such as IBM are not expanding in defense and some such as Eaton have sold their defense business. Many companies who want to stay in defense are faced with some tough management decisions for they see a rise in risks not being offset by higher returns.

Defense contractors need to be made responsible for their actions. However, government policy reforms are not the total answer. In fact, the policies may have a negative impact of driving suppliers out of defense, thus raising ultimate procurement costs.

An acquisition strategy is needed that recognizes the technical risks and is fair to both the government and contractors. Programs should begin competitively with a minimum of two teams competing for FSED. Competition would include definition studies that define system architecture and potentially high-risk elements of the system. Also, competition would include risk reduction efforts that further refine system design together with breadboarding and demonstration of key elements and subsystems. The scope of the definition studies and risk reduction efforts should be well enough defined such that they could be conducted under firm fixed price contracts. While the contractor will invest some of his own funds due to the competitive environment, his overall contribution at this point would be small (i.e. less than 5% of the FSED costs). Due to cost constraints, extended competition is probably not affordable, and one contractor team should be selected to carry-out FSED and production. "Not to exceed" production options should be included in the FSED contract.

Today the tendency is to let firm fixed price FSED contracts for programs that have medium to high technical risks. The Advanced Tactical Fighter program is a good example. Each of the two contracting teams has a firm fixed price $691 million contract to build two prototypes as well as a ground avionics demonstrator by 1990. The Air Force procurement strategy forces the contractors to shoulder far more of the technical and financial risks than in previous new fighter programs. Each team is expected to

invest between $300-$400 million.(8:35) If a FSED contract has medium to high technical risks, it is not fair for a contractor to assume the majority of the cost risks. An extremely difficult working relationship will be created between the government and contractor plus the contractor will most likely implement "work arounds" that result in a product that does not meet government specifications.

A fairer approach would be for the government to share the majority of the FSED cost risks until technical risks are reduced to a lower level. If costs exceed an agreed upon target, the contractor would begin his contribution by first sharing his profit (fee) then 10% to 20% of the cost overrun. The majority of cost risks still remains with the government. While the government's total liability is unknown, the required funds based on the government's cost estimate should reflect a 25% to 50% reserve to offset program risks. Under these circumstances, a constructive working relationship will exist between the government and contractor. Also, the program has a better chance of meeting performance specifications since the contractor is not bearing the majority of the cost risk. If a contractor will not commit to limited cost sharing, this should be an indicator that too much technical risk exists, and the program belongs back in research and development versus FSED.

Once the design becomes reasonably firm and technical risks are reduced to a moderate to low level, a firm fixed price contact should be considered for the remaining development, integration, and test efforts. This point would occur after the engineering development model passed a system demonstration test conducted in the contractor's integration laboratory.

FSED would continue with the development of qualified (preproduction) systems. Production would follow under firm fixed price contracts. (R4)

This acquisition and contracting strategy is not quite in line with current procurement thinking. As mentioned, the tendency is to let a firm fixed price contract at the beginning of FSED which is too early. Until the design becomes reasonably firm, the government should assume the majority of cost risks. If we force the contractor to accept these risks, we are likely to get a product that falls short of technical performance requirements.

SOURCE SELECTION

Traditionally, the source selection process has been a long, cumbersome effort that can take up to a year for completion and cost both the government and contractors millions of dollars. Often the return is not worth the investment. An obvious outcome of the process should be the selection of a contractor team that has demonstrated the capability and capacity to accomplish the contractual tasks. In many cases this does not happen, and soon after contract award, the program runs into trouble. The EW APC program experienced serious management and technical problems six months after contract award. The contractor team did not have the capability or capacity to develop the required software programs. The program was eventually cancelled after the contractor experienced cost growth of 100%.

Current Source Selection Process

Source selection is a formal, well structured process that evaluates a contractor in several criteria areas such as technical, management, manufacturing, logistics and cost. A contractor is evaluated against each area using specific criteria and standards. On the surface, the process should work. However, if a contractor can put together an impressive proposal plus submit a low cost, he stands an excellent chance of winning the contract.

The formal source selection process needs to be restructured. The government should be able to select a contractor within three to six months after proposals have been submitted. If the government has done its job in defining the performance and contractual requirements, then three to six

months is more than adequate. Unfortunately, this usually does not happen: the government enters source selection with ill defined requirements and contractual inconsistencies. Under these circumstances, the government and contractors attempt to reach understandings through a formal and time consuming process of contractor inquiries and deficiency reports. After several iterations, the contractors are given a final chance by submitting their "best and final offer (BAFO)". By this time technical leveling has occurred, and a contractor that submits the lower cost stands a good chance of winning. The EW ARC program was awarded to the lowest bidder.

Recommended Improvements

The government must do a better job in defining the critical performance and contractual requirements. Prior to requesting formal proposals from industry, the government package needs to be thoroughly reviewed by an experienced team. This often is not done. Next, the package should be reviewed informally with potential contractors. At this time, requirement ambiguities can be readily identified and resolved. While this process does take some time and resources, it is done in a less constrained, less formal environment which should not require as much time and resources as the formal contractor inquiry and deficiency reporting process mentioned earlier. Given a quality requirements package, contractors should be able to respond by submitting one and only one proposal. In other words, the contractor should be given one chance to respond. The formal process of contractor inquiries, deficiency reports, and BAFOs would be eliminated. This would reduce the source selection process by three to six months. (P5, 6)

By reviewing a contractor's proposal, the government will obtain some insight into a contractor's ability to perform. However, this is superficial, and more needs to be done. To determine a contractor's ability to perform, a capacity/capability review should be conducted at his plant during source selection. Currently, this may be done on a limited basis but needs to be expanded and include a review of all critical source selection areas. At a minimum, the technical, management, manufacturing, and cost areas should be reviewed. During the on-site review, a government team would conduct a series of controlled interviews, tour critical facilities and examine critical contractor processes and procedures to determine if the contractor can perform. Each review would last two to three days, would be extremely thorough and would address the essence of a contractor's proposal. Actual strengths and weaknesses could be readily identified. For a brief time the contractor would be put under a microscope, and his infrastructure examined in terms of skills, experience levels, procedures, discipline, technical strengths, systems engineering/analysis and company resources. While a contractor can make a proposal look good, he can not easily cover up weaknesses during this review. (R7)

Also as part of this review, contractor past performance should be examined. In source selection, past performance often is not reviewed or if reviewed, it's discounted. A lot of insight into a contractor's ability to perform in the future can be obtained by examining his past. The on-site government plant representative and program offices that have worked with the contractor provide excellent sources of information.

As previously stated, EW systems are tremendously complex and present significant procurement challenges. The government must obtain insight into

a contractor's ability to perform, which the present source selection process often does not provide. We can be lured into false hopes by a contractor's enthusiasm or by the contents of his proposal when in fact he doesn't have the infrastructure and control mechanisms in place to deliver a quality product in the required quantities. For example, it is not uncommon to find a technically sound engineering house that can build one or two systems in a laboratory environment but doesn't have the capability or capacity to transition from engineering into production. Without an on-site review, this may be very difficult to uncover.

By doing a more thorough job in reviewing the government requirements package, by conducting reviews at contractors' plants and by examining contractor past performance, we should be able to realistically assess a contractor's ability to perform. If a contractor does not have credibility, he should not be awarded the contract. The burden rests on the government to determine this through the source selection process.

GOVERNMENT/CONTRACTOR TEAM

The government program office and contractor organizations can make or break a program. This is particularly true of EW programs with their fast paced, high-technology activities.

Government Team

Over the years, the tendency in the Air Force has been to "do more with less". In terms of EW, we have increased the number of programs , but at the same time have not increased the number of government personnel to implement them. To make up for shortfalls in personnel, we have developed matrix organizations consisting of various functional disciplines such as engineering, contracting, financial, manufacturing and logistics. Figure 1 shows the program organization for the F-4 Advanced Wild Weasel program conducted during 1969-1978. The program office consisted of about 23 people assigned directly to the program supported by a couple of matrix personnel. Figure 2 shows the program organization for the F-4G Wild Weasel PUP during 1984-1987. The purpose of the PUP was to replace the Wild Weasel's processor and receiver subsystems which represent over 75% of the Wild Weasel avionics. The program office consisted of six people who were supported by approximately 14 matrix personnel. Two trends should be apparent; the relative junior level of personnel and the lack of dedicated engineering support. In 1980, matrix organizations at Aeronautical Systems Division were directed by its Commander to offset limited personnel resources.(1)

While the matrix organization allows coverage of many programs, we often fail to develop the expertise and continuity necessary to effectively

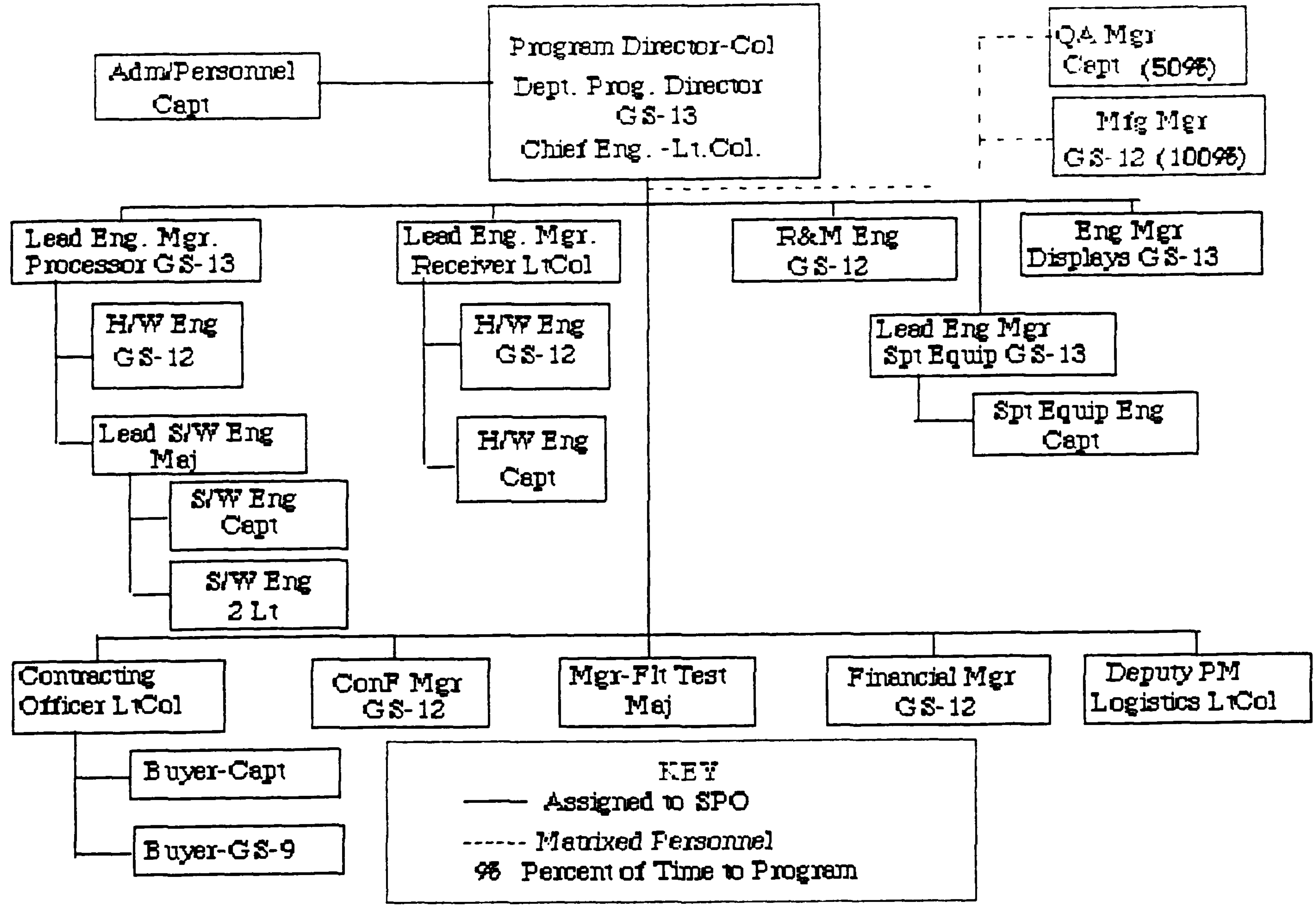

Fig. 1- F-4 Advanced Wild Weasel Program Organization 1969-1978

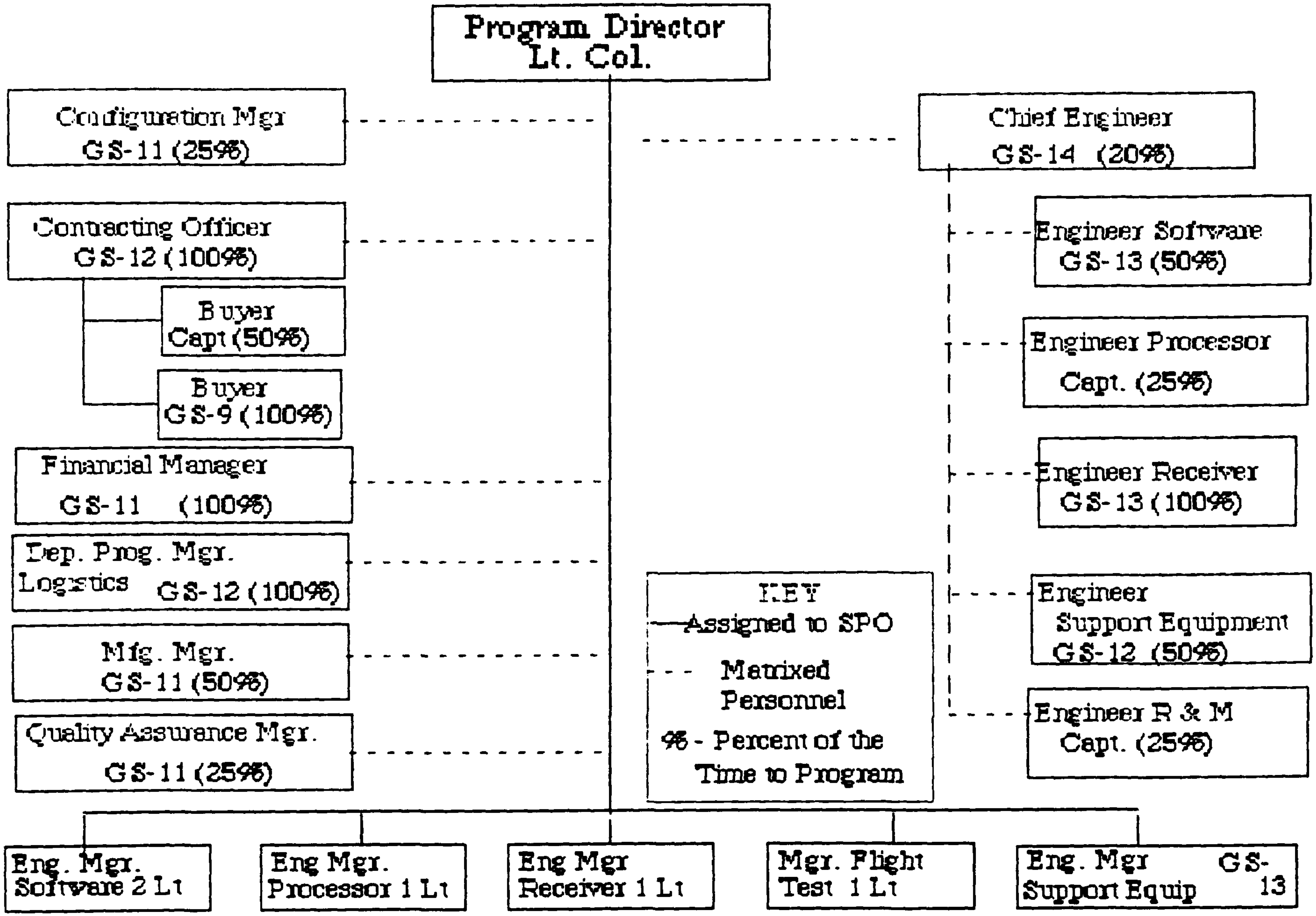

Fig.2-F-4G Performance Update Program Organization 1984-1987

manage specific programs. Under these circumstances, the government often performs the role of administrators and becomes totally dependent on the contractor. The matrix organizations are probably here to stay, and management must find creative ways to be productive within this organizational framework.

A primary goal of management is to establish and maintain program control of technical, cost, and schedule performance. To control a program, an experienced team must be formed headed by a program director. The program director must be a dynamic leader in order to fight the budget battles as well as motivate the government and contractor team. From a management perspective, he should be thoroughly familiar with the acquisition process and have a solid understanding of EW technology. However, his leadership abilities are key to maintaining the required government support and keeping the program on track. Without a dynamic leader, support for the program can quickly erode, and contractor performance can come off the rails within a matter of weeks. That is the nature of EW programs.

Program managers (referred to as engineering managers in figures 1 and 2) are dedicated 100 percent to a specific program and should be self starters. Additionally, for large EW programs, some critical positions exist which must have dedicated people either co-located to the program office or dedicated 100 percent from the matrix organizations. These critical positions consist of the chief engineer, lead subsystem engineers, the contracting officer, and the financial manager. These individuals, along with the program director and managers, form the core of the program office. If these positions are not filled with experienced people who are

dedicated 100 percent to the program, the government will not have the required visibility and will not be able to control performance. This may be one of the biggest shortcomings of EW management; we don't have strong enough program organizations to manage the acquisition of highly complex EW systems. This situation has led to more reliance on the matrix organization for the majority of support. (R8)

In a matrix organization, obtaining loyalty from the functionals can be difficult. The program manager does not control their performance ratings and normally can not hire or fire. Matrix individuals typically support several programs, and it's hard for them to get interested in any particular one. Program managers must create a positive working environment for matrix personnel primarily by creating a team approach, delegating responsibility whenever possible and giving credit for successes. The core of the program office is too small and does not have enough expertise to get the job done by itself. Matrix personnel can and must contribute to the program; it's up to the program managers to provide the direction, motivation and positive work environment. (R9)

Over the years, the Air Force has experienced a serious problem with keeping engineers. Currently, we have an adequate number of junior engineers, but not enough experienced senior engineers. A comparison of the program organizations represented in figures 1 and 2 shows that junior officers are now given the engineering management responsibilities that were previously assigned to majors and lieutenant colonels. While the junior people are highly motivated and dedicated, they simply don't have the experience. In a high technology field such as EW, this has really degraded our ability to gain visibility into contractor activities and in turn,

control the technical performance of the program. Unfortunately, the situation is getting worse. To offset the insufficient number of experienced engineers, consideration should be given to hiring civilian engineers through a "support services contract". This can be expensive. However, it can fill the void if experienced government engineers are not available. (R10)

The Air Force policy of reassigning personnel every three to four years does hurt the continuity of an organization and the government's ability to control the acquisition of EW systems. Within three to four years, an individual has gained not only the required experience level but also an in depth understanding of the complex interrelationships within the EW program. Frequently, new people are assigned without the experience, and they make the same mistakes of their predecessors. Unless an individual has failed, the Air Force should keep him on the program until a particular phase of that program has been completed. Reassignments should be based on completing a job versus time on station. Steps are being taken within AFSC to do this.(R11)

Finally, the program office must establish a close working relationship with key government agencies. These include higher headquarters, the user, the air logistics centers (ALCs), and test agencies. These organizations should be brought on board at the start, and their support continued throughout the life of the program. Representatives from these organizations should support design reviews, program reviews, and technical coordination meetings. Together they bring critical insights and concerns, which if acted upon by the program office, can result in a product that better serves the user both operationally and logistically.(R12)

Contractor Team

The problems inherent in a matrix organization, the inadequate number of experienced engineers and the lack of program office continuity have forced the government to rely more on the contractor to represent the government's best interest. Consequently it is essential that a positive working relationship and team effort be created between the government and contractor. Equally important is the contractor's organization. If the contractor does not have the infrastructure to implement the program, the program will fail; no matter how good the working relationship.

As a result of the capacity/capability review conducted during source selection, the adequacy of the contractor's organization will be determined. Because of the nature of EW, the contractor must have a strong technical background supported by an experienced systems engineering, analysis, and integration group. Also the organization that has responsibility for the manufacturing process is critical. Manufacturing processes and procedures must be in place along with the skills and discipline needed to follow them. (R13)

Each contractor has its unique organizational structure. However, critical positions such as the program manager, systems integration manager, chief engineer, systems integration engineer, and flight test director should exist with clear lines of authority. If these critical positions don't exist, are manned on a part time basis, or are buried within the contractor's organization, the organization is flawed and will lead to trouble.

Program Office and Contractor Relationship

The contractual arrangement dictates the formal working relationship between the government and contractor. Also, the informal working relationship becomes equally important in getting things accomplished. This does not imply that contractual direction is given through the informal working relationship. However, on a daily basis discussions of problems, impacts, and corrective actions occur so that both the program office and the contractor are kept informed. In other words, through this process one tries to minimize the element of surprise and maintain control. Timely problem reporting and corrective actions help keep the program on track. Occasionally, the government program manager should meet with the president or vice president of the company. This lets the contractor know that the program is important to the government. Also contractor upper level management can use this opportunity to reaffirm the company's commitment.

Role of the Systems Integrator

An experienced systems integrator with a strong management and technical background is required throughout all acquisition phases. For some EW systems, such as the B-1's defensive avionics program, the Air Force has performed the systems integration role with disappointing results. Basically, the government does not have a strong enough technical background or the experience levels required to perform the integration role of large, complex EW systems. Typically, this role rests with a prime contractor who subcontracts the various subsystems (i.e. receiver, processor, jammer, and displays) of the EW system. Unfortunately, few successful integration contractors exist in EW.

Air framers tend to be too regimented, narrow focused, and over burdened with a bureaucracy that parallels the government. Often they are not structured to integrate complex EW systems into airframes. Their organizations prevent them from cutting across the different functional disciplines and integrating the various program elements (be it hardware, software, or support equipment) into a system. Often they avoid accepting systems integration responsibility and pass that responsibility to their subcontractors through premature specifications. For example on the Wild Weasel PUP, the systems integrator managed his subcontractors primarily through detailed subsystem specifications. However in reality, the subsuystem specifications could not be realistically defined until the technological risks were reduced and the design stabilized. As a result the subcontractor never applied a systems approach to his design which resulted in a system that fell short of performance requirements. While subsystems specifications are improtant, the systems integrator should have placed more emphasis on the broader systems engineering and analysis functions before firming up detailed specifications.(4:11-13)

Some EW programs have assigned integration responsibility to avionics houses. For example, the prime contract to upgrade the EF-111 jamming system was awarded to Eaton's AIL Division versus Grumman or General Dynamics, the aircraft manufacturers. While this is a relatively new initiative, it too can have problems. Avionics contractors typically have expertise in a particular field such as receivers or transmitters. They are specialists and may not have the breadth of management or engineering experience to act as systems integrators. They also may not have the resources required to support the program. Finally, they may lack the

leverage to control the aircraft manufacturer, who may resist being put into a secondary role.

Systems integration contractors have been successful primarily through their organizational structure and company commitment to programs. For new aircraft programs, these contractors need to be singled out for future business (if they are an aircraft company) or teamed with the aircraft company that would produce the new airframe. For modification programs, aircraft companies that have a positive integration track record or systems integration contractors should be considered. The former category may be a company different than the original aircraft manufacturer. The latter category may not necessarily be airframers or avionics houses but companies that specialize in modifying and integrating avionics systems into existing aircraft. Systems integration remains the biggest challenge to EW, and we must do a better job in selecting a prime contractor that is up for the task. (R14)

PROGRAM CONTROL

According to Representative Les Aspin, government and contractor management places too much emphasis on meeting schedules. Aspin believes "the key concern of management is to push the goods out the door".(7:16) In attempt to meet schedules, too much concurrency often exists between development and production. As a result, we end up with systems that fall short of performance requirements and require costly retrofit programs. The B-1's defensive system represents a good example of a program that had too much concurrency and is now undergoing an expensive retrofit.

Given the high technology associated with EW systems, technical performance and program cost need to be tightly controlled. However, program management should not impose arbitrary deadlines on FSED and production schedules. A management plan needs to be established that ties key program decisions such as the delivery of hardware, the start of flight testing and production to the contractor meeting specified performance milestones. The program then becomes event versus schedule driven, which allows management to better control program risks. The program should not be allowed to proceed from one event to another until the contractor satisfies specific performance milestones. (R15)

Technical Performance

Often the government lacks timely insight into the technical performance of an EW system. According to General Welch, Air Force Chief of Staff, the Air Force "was badly surprised by the lag in the development" of the B-1's defensive system.(3) This can result from not being involved in the development process and from only monitoring formal tests. In order to

control technical performance, government engineers must track performance early on. This can be accomplished by initiating several actions with the contractor.

The contractor must implement an orderly FSED process that consists of breadboarding critical functions/subsystems and developing an engineering model/prototype. In general, the latter has the form, fit, and function of the final product but cannot perform under all environmental conditions. This process will reduce development risks and must precede the development of qualified systems. Tracking contractor events associated with the development and test of breadboards, engineering models, and qualified systems should begin at the shop replaceable unit (SRU) level and continue through the system level. (R16)

Government engineers should establish indicators to track the contractor's technical performance. These indicators are derived from the system level development specification and over time are translated into subsystem, LRU, and SRU indicators. For example, a system level indicator of sensitivity could be translated to a noise level figure at the SRU level. By doing this, the government can track progress as the lower-level design matures into a complete system. (R17)

Also, the development of test equipment and test procedures need to be tracked both at the informal and formal testing levels. Frequently the development of test equipment and procedures lag the development of the prime equipment. Consequently, a contractor will not have the required resources in place for testing the prime equipment which leads to inadequacies and cost/schedule impacts. The contractor should have his test

resources checked out prior to the start of prime equipment testing; be it at the SRU, LRU, or system levels. (R18)

The government has implemented a formal review process consisting of preliminary and critical design reviews. While these reviews serve a useful purpose in determining the maturity of a contractor's design, more effort is needed in terms of follow-up reviews. As the design progresses and hardware becomes available for testing, numerous design changes are required to correct deficiencies and oversights. This process needs to be closely tracked in order to maintain configuration control, quality assurance (QA), and design integrity. Periodic government/contractor reviews are needed to assess test results, determine the extent and impact of redesign, and verify the contractor is following a redesign process in accordance with company practices/procedures. For example, the reviews could be conducted as mini-critical design reviews on each *SRU and LRU* prior to releasing them to manufacturing. The contractor review team would consist of a small group of senior engineers from each functional area such as systems, electrical, mechanical, quality, and manufacturing and would be led by the chief engineer. The government would attend as an observer. (R19)

Finally, government engineers need to be physically located at critical contractor facilities. They can not gain enough visibility into contractor activities by only reviewing documentation sent to the program office or by relying on government plant representatives (i.e. AFPRO) who serve primarily in a contract administrative role. On site coverage, while a demanding challenge, will give the government the required insight into contractor progress, design stability and the magnitude of design problems. Under the matrix organization, government engineers may be reluctant to spend extended

periods of time at a contractor's facility; other programs they support will suffer. If government engineers aren't available, the program office needs to rely on a "support service contractor" to offset this shortfall. (R20)

Cost Performance

Formal cost performance reporting by the contractor can be a wasted effort if the contractor does not have a validated system in place or the discipline to follow it. This area should be closely reviewed during source selection, and a plan to resolve any problems implemented. Cost reporting would apply to the prime contractor as well as the subcontractors and should be conducted under both cost and fixed price contracts.

Contractor cost reporting can give the government insight into what the contractor believes the program will cost. This is based on the contractor's annual update to his cost estimate at completion (EAC) and by comparing the EAC to the contracted cost. Also, advance warning of problems can be gained by comparing the contractor's budgeted cost and schedule to his actual cost and schedule. Contractor tasks should be broken down into specific work packages with starting/stopping dates and budgets assigned to each work package.

Prior to the contractor running into cost problems, the government-contractor team needs to take corrective actions. These actions include reducing development concurrency, performing risk reduction efforts, performing early environmental testing, following quality assurance practices/procedures and reducing/eliminating contractual requirements that add little value to the end item. All these actions are aimed at uncovering

problems and taking corrective measures at earlier, less costly stages of the design process. (R21)

The government should also go through an annual exercise to update the "most probable cost" for completing the program. This cost estimate is broader than the contractor's EAC since it includes all contractor and government activities. For a cost type of contract, the government should budget to the "most probable cost" since this represents an estimate of the government's potential liability and should reflect program risks. (R22)

As with most high technology programs, cost growth can be expected. Under these circumstances, the program office must first examine zero cost growth alternatives. Usually no viable alternative exists within FSED such as reducing the number of qualified units or reducing the amount of testing. All end items and tasks within FSED are required in order to maintain program integrity. That leaves the production program. Typically, cost growth in FSED is offset by transferring some funds earmarked for production which under zero cost growth results in reduced production quantities.

Another approach to offset cost growth is to restructure the FSED program such that the required and approved funds match in the current and upcoming budget years. The restructure stretches schedules by moving certain tasks into the out-years. Cost growth then occurs in the out-years where it can be addressed through the normal POM process. While it is highly desirable to avoid cost growth, this may be impossible and should be worked in an orderly manner by first examining zero cost growth alternatives and then by working any remaining cost problems in the out-years. (R23)

Schedule Performance

Schedules should reflect the time required to realistically implement the high technology associated with EW systems. If government emphasis is placed on meeting technical performance requirements and budget constraints, then schedules must minimize concurrency between developing an engineering model/prototype and qualified (preproduction) units as well as between FSED and production. Schedules should not be success oriented but should have built in contingencies that reflect additional time that will be required for redesign and retest. Special attention should be given to system integration and ground testing. These activities are the most complex, but we consistently underestimate the time required to complete them. If slips occur during FSED, a tendency exists to compress the time allocated for integration and ground testing in an attempt to catch up. This approach rarely works and usually results in failure to identify and correct serious performance problems. During flight testing and production, these problems eventually will be discovered and will have to be fixed through an expensive retrofit program. Better to spend the time early on to properly integrate and test the system. (R24)

If more emphasis is placed on technical performance and cost, that does not imply that program schedules should float. A moderate amount of schedule pressure needs to be applied to contractors for them to perform efficiently. In some cases, a lot of pressure will be applied in an attempt to meet a critical program milestone. However, in order to avoid contractor burn out and maintain efficiency, extreme schedule pressure should be used only under exceptional circumstances. As a compromise between "trying to

get something out the door" and "engineering the design to death", program schedules should reflect a moderate amount of risk (i.e. somewhere between 50% and 75% chance of success). A program with moderate risk schedules can be kept on track given close management attention and contractor commitment. As problems surface, management attention should be applied in terms of implementing work arounds, adjusting resources, or forming special teams to solve problems.

A common problem with many EW programs is that flight testing and production start too soon. We end up fielding EW systems that operationally can't perform, and logistically can't be supported. In part, this results from too much emphasis placed on meeting schedules and pushing too much concurrency between development and production. To correct this problem, performance milestones within FSED should be completed prior to the start of flight test and the award of production. These would be coordinated and agreed upon by the program office, government test agencies, and the contractor and would be reflected in the acquisition strategy for the program.

For example, prior to the start of flight testing, the EW hardware and software should be integrated at a ground test facility (e.g. integration laboratory). This allows the contractor to test the system under a controlled environment. Next, the system should be integrated into a test aircraft, and checks made on the ground to verify performance. While this environment is less controlled than in a laboratory, it does provide more control than in a flight test environment. Also, all flight test support activities and equipment should be in place and operational. This includes flight test instrumentation, data reduction systems, special test equipment.

maintenance equipment and documentation. Prior to the start of flight test, all problems that have been previously identified will not be solved but should at least have corrective actions identified. By requiring the contractor to pass performance milestones prior to the start of flight test, an orderly transition into flight test will occur. (R25)

A similar approach can be used to enter production. Typically, production consists of phases; the first being a low-rate initial production (LRIP) startup followed by full production options. An LRIP decision usually supports an initial operational capability and allows the contractor to get the production tooling in place and transition into a production environment. LRIP could be thought of as a risk reduction effort taken prior to full production award.

For LRIP, some FSED milestones should be completed prior to contract award. These include system integration testing, some environmental testing, laboratory reliability testing, and some flight testing. Enough testing should be completed to give the government development and operational test agencies high confidence that the EW system can meet in-flight performance requirements. For full production, FSED should be completed prior to contract award. During the remainder of FSED, most of which would consist of flight testing, emphasis would be placed on field reliability, maintainability and support equipment associated with the EW system. By minimizing the concurrency between FSED and production, this approach should result in production systems that meet the operational and logistics requirements. (R26)

Problem Tracking/Corrective Action System

To tie program control of technical, cost, and schedule performance together, the government/contractor team should implement a problem tracking and corrective action system. This system cuts across all government and contractor functions, is consolidated between the prime contractor and subcontractors, and should be implemented at the start of FSED. For each problem a brief description, status, impact and get well date would be included as part of corrective action summaries. The prime contractor would maintain the system. Problem status would be reviewed at the various technical coordination meetings and test planning working groups.

FULL SCALE ENGINEERING DEVELOPMENT

The government knows from past experience that FSED consists of significant technical risks. Time must be allocated, and steps must be taken to reduce these risks. (R27)

Risk Reduction Steps

The contractor must perform the necessary systems engineering to translate system requirements into detailed design requirements. For those risk areas, breadboard development and testing should be conducted at both the LRU and functional levels. Testing should be conducted using informal procedures, and results should be recorded in at least an engineering notebook. While the test environment remains informal, some discipline is required to maintain an orderly development process and configuration control; following test procedures and recording results help provide that discipline. Environmental surveys (i.e. limited environment testing) should be conducted on the more complex components and circuits. This helps establish design integrity early in FSED. (R27a, R27b)

In today's high technology environment, gate array and very high speed integrated circuits are used to achieve miniaturization and increased through-put. Due to design complexity, design implementation and rework can be very time consuming. Before releasing these circuits from design to the build process, the contractor should perform extensive simulation of both the inter and intra circuit operations. Simulation will uncover logic errors, timing errors, and reduce the number of rework cycles all of which can save months in the schedule. (R27c)

Next, an engineering development model should be built. The model incorporates the breadboard design and should be used to demonstrate the functional performance of the end item. Test emphasis focuses on the SRU, LRU, and system levels. For each level, test procedures are developed, test results are recorded, and design requirements are further defined. A subset of the test procedures will be used by the prime contractor and government to support the formal acceptance test conducted on qualified systems. Developing test procedures in conjunction with the engineering model will save valuable time during formal testing. (R27d, R27e)

In parallel to the development of an engineering model, test equipment hardware and software must be developed in time to support testing at the SRU, LRU, and system level. (R27f)

Once the engineering model has been integrated and tested at the system level, a *redesign cycle* may be required prior to building qualified systems. The number or magnitude of design changes may be so significant that several SRUs and LRUs require extensive redesign. To proceed further into FSED would incur too much technical risk. At a minimum, the functional performance of the engineering model should be demonstrated before building qualified systems.

When building qualified systems, the contractor should follow sound manufacturing procedures and practices. Some contractors will build FSED units in an engineering laboratory environment which does not provide the manufacturing control to track design changes or produce quality products. A balance must be established between the engineering and production environments. Building a system in a laboratory can result in systems that fail to perform since quality assurance procedures may not be closely

followed. On the other hand, a formal production environment can stifle design progress if fully applied during FSED. Ideally, production qualified personnel following approved manufacturing procedures should build the qualified units. However, the process should be streamlined to allow red-line drawings, a quick but controlled approval cycle for design changes, and a reasonable number of jumper wires per SRU.(R27g)

The prime contractor should provide on-site quality assurance coverage at major subcontractor facilities. The QA representative would be involved in subcontractor day to day activities. Government QA representatives would perform spot checks during the build process and inspections of the end item during formal acceptance testing. This approach will expedite the build cycle by streamlining the government's formal involvement and will maintain control of subcontractor activities through on-site coverage by the prime contractor. By controlling the manufacturing process during FSED and designing in quality early on, end items will be better able to withstand the formal environmental and flight testing that follow. (R27h)

Systems Integration

Systems integration should follow a phased approach. The first phase would consist of integration of the hardware subsystems such as the receiver, jammer and processor subsystems. A building block approach would be used that eventually tests all LRUs integrated on a test bench. In parallel, the operational software would be integrated starting at the module (component) level as well as at the functional level. For example, the receiver control module would be integrated at the component level, and the capability to detect, process and display a threat would be integrated

at the functional level. Functionally, software from several modules such as executive control, receiver control, pulse processing and display would be tested. Software integration would proceed until the complete operational program was integrated. A software integration facility would be used that consists of a host computer to simulate the airborne hardware and signal environment. Ideally the airborne processors that host the operational software along with the EW control and display subsystem would be a part of the software integration facility. Also, avionics and weapons simulators would be included to provide a check of the software interfaces at the system level. (R28)

After the EW hardware has been integrated and has passed a functional demonstration test (engineering model) or an acceptance test (qualified units), system integration testing can begin. This represents the second phase of integration. System testing continues until all EW hardware and software have been integrated. An integration bench is used consisting of aircraft wiring, avionics and weapons simulators, along with the EW hardware. The emitter environment can be generated either by hardlining signals aft of EW antennas or by using an anechoic chamber where signals are received at the antennas.

Once this phase is completed, the system is ready for integration into a flight test aircraft. This represents the third phase of integration testing and is conducted on the ground. Testing should include continuity checks, an electromagnetic compatibility test, and limited performance tests. Consideration should be given to using a facility similar to the Navy's anechoic chamber at Patuxant River, Md. The chamber is large enough to house an aircraft and provides an excellent signal environment under

controlled conditions. While future plans exist, the facility currently does not have the capability to test EW systems that use phase interferometers for direction of arrival (DOA) measurements. However, the chamber can test systems that use signal amplitude to determine DOA. Following aircraft integration testing on the ground, the system is ready to enter flight testing; the final phase of integration.

If these phases are not performed or are not followed in a systematic and orderly manner, then flight testing will fail. Past experience bears this out. In the future, we must take the time to integrate the EW system both in the laboratory and on the aircraft prior to beginning flight test.

Flight Testing

Flight testing during FSED consists of development test and evaluation (DT&E) and initial operational test and evaluation (IOT&E). For each, a responsible test organization (RTO) and test director are selected. For DT&E, the RTO could be either the test wing at Edwards AFB or Eglin AFB. For IOT&E, the RTO could be the Air Force Operational Test and Evaluation Center (AFOTEC). An efficient way to conduct flight test consists of a joint Air Force/contractor DT&E and a combined DT&E/IOT&E.

Throughout FSED, the flight test team must be involved in the FSED process by attending meetings, reviews and ground tests as well as reviewing technical documentation. To effectively test the EW system, the test team must have a detailed understanding of the system's design and its expected performance. The only way to obtain the required insight and level of expertise is through involvement in the program. While AFOTEC has done a good job of this, the DT&E flight test community has not. (R29)

During DT&E, a tremendous amount of in-flight data will be recorded by the instrumentation system, most of which will never be reduced or analyzed. To focus the trouble shooting process, a procedure should be followed to identify problems that occurred during a flight and reduce/analyze the data associated with those problems. This effort should be accomplished before each mission. Flight test problems can be identified through crew debriefings but more importantly, through a review of the video recordings of the EW displays. From reviewing the video recordings, problems can be tagged with their time of occurrence. The associated data recorded by the instrumentation system can be reduced for further analysis which would help guide the trouble shooting process. Given an automated instrumentation and data reduction system, problems can be identified and data can be reduced/analyzed within 24 hours.

Often success in flight test is measured in terms of flying rate. This can represent a false indication of success if data analysis and trouble shooting does not precede mission planning. At the beginning of DT&E, a significant amount of time will be spent trouble shooting problems on the ground using both the integration bench and test aircraft. At best, flying once every week to ten days would be productive. Once the initial DT&E start up problems are solved, then flying 2 to 3 times per week could be achieved. A higher flying rate results in test inefficiencies. The test team can't keep up with analyzing the amount of recorded data. Also, an insufficient amount of time will be available for trouble shooting and maintenance activities.

During DT&E, test emphasis would be first placed on development and then placed on demonstrating the performance requirements contained in the

system specification. Since the contractor should be contractually responsible for in-flight system performance, data should be gathered to support the contractor's efforts to identify and fix problems. At the start of testing, configuration control must be established and maintained; particularly with the operational software. During flight test, hundreds of software changes will be made to correct problems. If these changes are not checked out by the contractor in the software integration facility, on the integration bench, and on the aircraft prior to flight test, then flight testing will soon get out of control. For all software changes, test procedures must be established and followed, documentation updated, and the test team briefed on expected impacts. The test director should have final approval on test configuration and whether a change is ready for flight test. Once system design begins to stabilize, then data can be gathered to demonstrate system performance. At this time the transition would begin into IOT&E. (R30, R31)

Prior to IOT&E, consideration should be given to transferring some of the operational software maintenance responsibilities to the appropriate air logistics center. To support this approach, the ALC would require early delivery of the software support tools and documentation required to maintain the operational program. The goal would be for the ALC to generate an operational program to be used during IOT&E. Achieving this goal would help demonstrate the ALC's organic capability to maintain the operational software for a particular EW system prior to the system's initial operational capability. In addition, the ALC could perform a software verification and validation effort for the program office. (R32)

The DT&E and IOT&E flight test communities must measure performance using consistent and agreed upon pass/fail criteria. In the past, DT&E has been conducted using broader or different criteria than used in IOT&E, resulting in the EW system failing IOT&E. Prior to the start of flight test, the pass/fail criteria for DT&E and IOT&E should be derived from the system specification and agreed upon by the program office and both RTO's. If differences exist, they must be resolved prior to the start of flight testing. Once an agreement is reached, the pass/fail criteria should be formally documented in a Baseline Correlation Matrix. (R33)

Similarly, criteria should be established for the transition from DT&E to IOT&E. It would be senseless to enter IOT&E knowing in advance that the system will fail. The criteria would include demonstrating an agreed upon level of performance during DT&E for both prime and support equipment, a reassembled operational program with updated software documentation on site, and validated technical orders on site. These criteria would be documented in the Test and Evaluation Master Plan. (R34)

To support the LRIP decision, IOT&E emphasis should be placed on providing an assessment of operational performance. Once the design is stabilized during DT&E, as much performance data as possible should be used to support the IOT&E assessment. This would help to expedite the LRIP decision. As IOT&E progresses and to support the full production decision, more emphasis should be placed on evaluating technical orders, support equipment and reliability/maintainability. (R35)

A positive and close working relationship must exist between the program office and the IOT&E RTO (i.e. AFOTEC). Production decisions are based primarily on IOT&E test results, and both organizations need to work

closely together to achieve a successful IOT&E. For example, as problems are identified during IOT&E, the program office must work with the contractor to identify corrective actions. In some cases, problems can be corrected during IOT&E. For others, solutions will have to be implemented and demonstrated during follow-on testing or during production. The program office must be committed to solving IOT&E problems, and the RTO must be convinced of the program office's commitment. This can only come about through a close working relationship.

TRANSITION INTO PRODUCTION

As mentioned, production will occur in phases that may include a LRIP start up followed by multiyear options for full production. To reduce production risks and help assure a successful transition from FSED, an approach that minimizes concurrency between FSED and production can be implemented which ties production decisions to the contractor meeting specified program milestones. These should include FSED test milestones and equally important, should include successful completion of a production readiness review (PRR) and contract negotiations.

Production Readiness Review

A production readiness review determines whether or not a contractor is prepared to enter production. The PRR is based on the contractor's manufacturing plan and an extensive on-site review of the contractor's capability/capacity to produce the end item. The PRR addresses all manufacturing areas which include management, production facilities/resources, processes/procedures, quality assurance and risk. For risk areas, the contractor would be required to implement risk reduction actions before production award. (R36)

Contract Negotiations

As a step that minimizes cost risk to the government, the entire production contract (i.e. LRIP and full production options) should be negotiated prior to LRIP award. If initial production is awarded prior to completion of full production negotiations, the government will lose contractual leverage to control cost. (R37)

Contractual negotiations are a long and tedious process that can become a program driver. Therefore, adequate time must be allocated for the government to develop a requirements package, the contractor to prepare a proposal, the government to fact find the proposal and the government/contractor to complete negotiations. This process should begin 9 to 12 months in advance of anticipated production award.

To expedite the formal contractual process, the government and contractor should jointly review the requirements package informally and reach an agreement on the contractual specifications, statement of work, terms and conditions. If the government or contractor has to formally update the requirements package or proposal, this will take at least six months. Better to work the details out in advance and only have one requirements/proposal cycle.

The following sections address two specific areas, namely warranties and preprocurement data, that have caused difficulties during contract negotiations.

Warranties

If interpreted and implemented in its broadest sense, the Defense Appropriations Act of 1984 makes warranties a standard feature of most fixed-price production contracts. (5:5-62) Simply put, a warranty is a contractor commitment to deliver a product that meets specified standards for a specified period of time. In principle, a warranty makes sense. It provides a means for the government and contractor to share risks with respect to performance and provides an added incentive for the contractor to design and produce a quality product. However, implementing a warranty can

be extremely complex and difficult to administer if steps are not taken to develop and coordinate a warranty strategy prior to production award. (R38)

As part of that strategy, four areas must be considered:

1. A procedure must be followed for defining and implementing a warranty. This would include performing studies to identify candidate approaches, coordinating approaches with engineering, user, logistics, and contractual personnel, and obtaining industry comments regarding preliminary terms and conditions. The warranty clause would become a part of the production requirements package. (R38a)

2. Specific performance parameters to be covered under the warranty must be identified. A good source is the system level development specification. Reliability and maintainability are the parameters typically addressed. Others may include operational performance parameters such as system sensitivity, dynamic range, reaction time, and system interfaces.(R38b)

3. Each performance parameter must be accurately measured against specific criteria in order for the warranty to be effective. Also, the contractor should not be committed to guarantee performance parameters beyond his reasonable control. For complex EW systems, his control will be significantly diminished in an operational (field) environment. In the field, the Air Force may not adequately track failures and perform the analysis necessary to determine the cause of the failures. Was the failure induced or inherent? Can it be repeated on the ground? Without answers to these questions, a contractor will be extremely reluctant to commit to performance guarantees that are measured in the field. (R38c)

An alternative approach would be to measure system performance in a laboratory which does provide a controlled environment. For example, reliability can be measured by conducting a test which consists of exposing the system to several failure free environmental cycles. Based on past experience, the system would have to demonstrate a reliability three to four times higher than the required field reliability.

4. A corrective action plan must be defined in the event that a performance parameter fails the warranty. Corrective actions could include the contractor providing additional spares or performing redesign/retest at no cost to the government. If additional spares are to be provided, then consideration should be given to sparing at the SRU versus LRU level. This will be more cost effective. (R38d)

The cost of a warranty varies from 3 to 7 percent of the production contract; it is expensive. To assure that the warranty will be cost effective, a well thought out and fully coordinated strategy must be developed and implemented.

Reprocurement Data

A general policy exists for the government to acquire the data that provides the capability to produce the end item by sources other than the original manufacturer.(5:5-18) When a sole-source production contract is awarded, the government is placed in the position of having to depend on the contractor for additional units, spares, and modifications. Acquiring reprocurement data can be used for component breakout from a prime contractor, to solicit other sources, or to possibly allow the government to produce/modify the item. However, a major disadvantage of reprocurement

data is cost, and a strategy to acquire this data must be well thought out. (R39)

Often, the program office defines the reprocurement data package without interfacing with the ALC that will have responsible for the end item. The ALC should tailor the reprocurement data to his specific needs. This will reduce costs. Secondly, reprocurement data should be broken out into two categories; the first consisting of detailed engineering and manufacturing drawings and the second consisting of the manufacturing procedures/processes used to produce the end item. Drawings can be acquired for about $100,000 per LRU. Acquiring the manufacturing procedures/processes will cost millions and should only be considered as a contractual option to be exercised by the ALC. Hopefully the ALC will only need the drawings. (R39a,R39b)

Finally, unlimited data rights may have to be acquired. Unlimited rights allow the government to avoid sole-source dependence. Because of the government's insistence that the contractor share more of the investment costs, we may see more limitations placed on the government in using technical data delivered as part of a contract. Acquiring unlimited rights can cost millions and should be treated similarly to acquiring the manufacturing procedures/processes. It may be more cost effective to remain in a sole source position than to acquire the data rights and manufacturing procedures/processes needed to develop an alternate source. (R39c)

A complete reprocurement data package will be extremely expensive. Most likely only a drawing package tailored by the appropriate ALC needs to be procured.

CONCLUSIONS AND RECOMMENDATIONS

The answer to successful acquisition management of EW systems can be summarized as follows:

1. An experienced government/contractor team is required that has a strong management, systems integration, and technical background.

2. The team must make the necessary resource commitments to the program.

3. The team must have in-place an infrastructure and the discipline to follow an orderly and controlled acquisition process.

4. Concurrency between development and production must be reduced, and a management plan implemented that ties key program decisions to the contractor meeting performance milestones.

Specific conclusions and recommendations are summarized in the following sections:

The Electronic Warfare Challenge

We must push technology in order to beat the Soviet EW threat. A reality of EW systems is high technology.

For EW systems, system integration presents the greatest technical challenge.

The technical challenges translate into high risk programs.

The Acquisition Management Problem

Because the state of the art is being advanced, technical performance uncertainties remain until actual hardware is developed, integrated and tested.

Program cost and schedule estimates tend to be too optimistic and do not realistically reflect the technical risks.

R1. For planning purposes, technical risks should be assessed as medium to high, schedules should be based on a 10 to 12 year acquisition cycle and budgets should be in line with technical risks/schedules. (p.8)

Development of Program Requirements

System performance requirements are often defined in terms of worst case threat scenarios.

Significant design improvements are needed to counter the threat, and obtaining the required EW capability will be expensive.

R2. As part of the requirements definition process, definition studies, risk reduction efforts and development of engineering models should precede the development of qualified (preproduction) systems. (p.10)

In today's environment of cuts in defense spending, programs that cannot stay within their budget are being cancelled.

R3. Management should base their cost and schedule estimates on a realistic assessment of technical risks which should be addressed up front before the acquisition cycle begins. (p.11)

An acquisition strategy is needed that recognizes the technical risks and is fair to both the government and contractor.

R4. Definition studies and risk reduction efforts should be competitive and conducted under fixed price contracts. One contractor team should be selected for FSED and production. Until the design becomes firm and technical risks are reduced, the government should share the majority of the cost risk under a "cost plus" type of contract. When the design stabilizes, the remainder of FSED could be conducted under a fixed price contract. Production should be conducted under a fixed price contract. (pp.13-15)

Source Selection

The formal source selection process is cumbersome, expensive and may not result in selection of the best contractor team. The process needs to be restructured.

R5. Prior to requesting formal proposals from contractors, the government requirements package should be reviewed by an experienced team and coordinated with industry. (p.17)

R6. Contractors should be given one chance to respond to a proposal request. The formal process of contractor inquiries, deficiency reports and BAFCs should be eliminated. (p.17)

R7. To determine a contractor's ability to perform, a capacity/capability review should be conducted at his plant during source selection. As part of this review, contractor past performance should be examined. (p.18)

Government/Contractor Team

To control a program, an experienced government team must be formed headed by a dynamic program director and consisting of program managers and matrix personnel from various functional organizations.

R8. In addition to the program director and managers, the chief engineer, lead subsystem engineers, contracting officer and financial manager should be assigned full time to the program. (pp.23-24)

R9. Program managers should create a positive working environment for matrix personnel by creating a team approach, delegating responsibility whenever possible and giving credit for successes. (p.24)

Currently, the Air Force does not have an adequate number of experienced senior engineers which has degraded our ability to control technical performance.

R10. Consideration should be given to hiring engineers through a "support services contract" to offset the shortfall of experienced senior engineers. (p.25)

R11. In order to maintain continuity, reassignment of critical positions should be based on completing a job versus time on station. (p.25)

R12. The program office should establish a close working relationship with key government agencies that can bring critical insights and concerns to the program. (p.25)

If the contractor does not have the company commitment and the organizational infrastructure to implement the program, the program will fail.

R13. The contractor team should have a strong technical background supported by experienced systems engineering, analysis, integration and manufacturing groups. (p.26)

The informal working relationship between the government and contractor becomes important in getting things accomplished and keeping each other informed.

An experienced systems integrator with a strong management and technical background is required throughout all acquisition phases. Few successful integration contractors exist in EW.

R14. For new aircraft programs, successful systems integration contractors need to be singled out for future business or teamed with the aircraft company that would produce the new airframe. For modification programs, systems integration contractors, who may be different from the original aircraft manufacturer, should be considered. (p.29)

<u>Program Control</u>

Too much management emphasis is placed on meeting schedules.

R15. A management plan should be established that ties key program decisions to the contractor meeting specified performance milestones. (p.30)

R16. The contractor should implement an orderly FSED process that consists of breadboarding critical functions/subsystems and developing an engineering model/prototype. (p.31)

R17. Government engineers should establish indicators to track the contractor's technical performance. (p.31)

R18. The contractor should have his test resources in place and checked out prior to the start of prime equipment testing. (pp.31-32)

Formal design reviews serve a useful purpose; however, more needs to be done in terms of follow-up reviews.

R19. To support the redesign process, mini design reviews need to be conducted on each SRU and LRU prior to releasing them to manufacturing. (p.32)

R20. To gain visibility into a contractor's activities, government engineers need to be physically located at critical contractor facilities. (pp.32-33)

Contractor cost reporting can give the government insight into what the contractor believes the program will cost.

R21. Prior to the contractor running into cost problems, the government/contractor team needs to take corrective actions. (pp.33-34)

R22. For a cost type of contract, the government should budget to the "most probable cost" estimate. (p.34)

R23. Cost growth should be worked in an orderly manner by first examining zero cost growth alternatives and then by working any remaining cost problems in the out-years. (p.34)

R24. Schedules should reflect the time required to implement the high technology associated with EW systems. Schedules should minimize concurrency between FSED and production. (p.35)

A common problem with many EW programs is that flight testing and production start too soon.

R25. Prior to the start of flight testing, the EW system should be integrated at a ground test facility and into a test aircraft. All flight test support activities and equipment should be in place and operational. (pp.36-37)

R26. Prior to initial production, some FSED milestones should be completed that include system integration testing, some environmental testing, reliability testing and some flight testing. Prior to full production, FSED should be completed. (p.37)

Full Scale Engineering Development

The government knows form past experience that FSED consists of significant technical risks.

R27. Time should be allocated and steps should be taken to reduce these risks. Risk reduction steps should include the following: (p.39)

a. Breadboard development and testing. (p.39)

b. Early environmental testing. (p.39)

c. Simulation of gate array and very high speed integrated circuits. (p.39)

d. Development of an engineering model and demonstration of its functional performance. (p.40)

e. Early development of test procedures. (p.40)

f. Early development of test equipment. (p.40)

g. Following sound manufacturing procedures and practices when building qualified FSED systems. (pp. 40-41)

h. On-site QA coverage at major subcontractor facilities. (p.41)

R28. Systems integration should follow a phased approach that consists of hardware integration, software integration, systems integration and aircraft integration. (pp.41-42)

An efficient way to conduct flight tests consists of a joint Air Force/contractor DT&E and a combined DT&E/IOT&E.

R29. To effectively test the EW system, the flight test team must be involved in all aspects of FSED. (p.43)

R30. During DT&E, test emphasis should be first placed on development then on performance. (pp.44-45)

During flight test, hundreds of software changes will be made to correct problems.

R31. For all software changes, test procedures must be established and followed, documentation updated and the test team briefed on expected impacts. (p.45)

R32. As a step towards demonstrating an organic software capability, some of the operational software maintenance responsibilities should be given to the appropriate ALC prior to IOT&E. (p.45)

R33. A Baseline Correlation Matrix should be generated that documents the DT&E and IOT&E test criteria. (p.46)

R34. The Test and Evaluation Master Plan should include the DT&E criteria that must be satisfied before starting IOT&E. (p.46)

R35. To support initial production, early IOT&E emphasis should be placed on assessing operational performance. (p.46)

Transition into Production

R36. To determine if a contractor is prepared to enter production, a production readiness review should be conducted. (p.48)

R37. To minimize government cost risk, the entire production contract (i.e. LRIP and full production) should be negotiated prior to initial production award. (p.48)

R38. Prior to contract award, steps should be taken to develop and implement a warranty strategy that includes the following. (pp.48-50)

a. A procedure for defining and implementing the warranty. (p.50)

b. Specific performance parameters to be covered under the warranty. (p.50)

c. Methods to verify performance against specified criteria. (p.50)

d. Corrective action plans in the event system performance fails the warranty. (p.51)

R39. Prior to contract award, a strategy to acquire reprocurement data should be developed that includes the following: (pp.51-52)

a. Strong coordination with the ALCs that will have responsible for the end items. (p.52)

b. Procurement of engineering drawings and as options, procurement of manufacturing procedures/processes. (p.52)

c. Procurement of unlimited data rights as options to the production contract. (p.52)

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GLOSSARY

AFOTEC	Air Force Operational Test and Evaluation Center
AFPRO	Air Force Plant Representative Office
AFSC	Air Force Systems Command
ALC	Air Logistics Center
ARC	Area Reprogramming Capability
BAFO	Best and Final Offer
DOA	Direction of Arrival
DT&E	Development Test and Evaluation
EAC	Estimate at Completion
EW	Electronic Warfare
FSED	Full Scale Engineering Development
IOT&E	Initial Operational Test and Evaluation
LPI	Low Probable Intercept
LRIP	Low Rate Initial Production
LRU	Line Replaceable Unit
POM	Program Objective Memorandum
PRR	Production Readiness Review
PUP	Performance Update Program
QA	Quality Assurance
RF	Radio Frequency
RTO	Responsible Test Organization
SRU	Shop Replaceable Unit